Automatic Machine Gaging

By C. W. ROBBINS

NOTE: This paper discusses the advantages to be gained in certain types of large scale production by the substitution of automatic machine gaging for hand testing. For testing carbon protector blocks, a machine has been developed which accepts all blocks in case a certain dimension lies between 0.0024″ and 0.0032″ and rejects those when the dimension is 0.0023″ or less or 0.0033″ or more. This machine will effect a saving of $8000 per year over the cost of hand gaging on an output of 4,500,000 blocks. The saving effected by another recently developed machine replacing a manual test is approximately $1200 a year on a production of 2,500,000 pieces, but a far more important consideration than this money saving is the elimination of an operation so monotonous that it was difficult to keep any operator on it for more than a brief period. The author points out that in some instances automatic machine gaging of the entire product will cost less than a sampling inspection in which there must be included in the direct cost of inspection the cost of some additional supervision and control.

THE cost of testing and gaging parts manufactured in large quantities frequently warrants the construction of special machinery for this work which may be more or less automatic in operation. At the Hawthorne Works of the Western Electric Company considerable study has been given to the problem during the past ten or twelve years and several such machines have been developed. The work has recently assumed more important proportions and many important developments have materialized in the last two or three years.

Some of these machines perform a single operation while others perform several operations successively. Some are automatically fed from a hopper; others are fed by an operator, who at the same time performs some visual operation. Usually each type of piece to be gaged forms a distinct problem, and a single paper to be most useful can be suggestive only as to the procedure to be followed and methods that may be used. To this end it seems best to describe with considerable detail some of the machines that are in successful operation.

Single Test Machine, Automatic Feed

A single purpose gaging machine with automatic feed is shown in Figs. 1 and 2. The part to be tested, shown in Fig. 2 (*a*), is used in the construction of switchboard plugs. It consists of a piece of 5/32 in. brass tubing, $1\frac{1}{2}$ in. long, having a sleeve soldered at one end and a plug soldered in the other. The machine applies a 50 pound test to the two soldered joints simultaneously.

Within the hopper *H*, Fig. 1, a shaft having three slotted arms is

revolved slowly through the ratchet R. The slotted arms pick up the parts suspended in the slot by the sleeve and deliver them into the chute A, Figs. 1 and 2. An intermittently revolving turret B, Fig. 2,

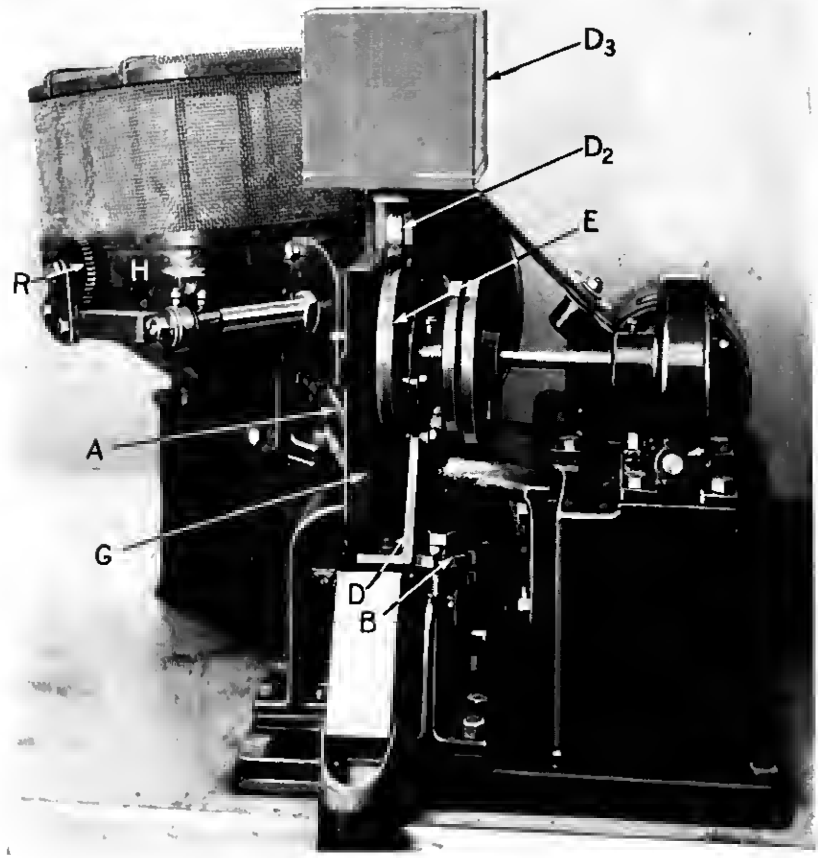


Fig. 1

having four notches or chucks, receives the parts from the chute and carries them under the plunger D, attached to the slide D_1, which carries the 50 pound weight D_3. The slide with the weight is raised and lowered at the proper time by the cam E acting on the roller D_2 attached to the slide.

After the turret has carried the part to the testing position and stopped, the plunger D enters the tube, gradually applying the load (furnished by the weight D_3) to the soldered joints X and Y, Fig. 2.

If either joint is defective, the weight and slide will not be supported but will drop to the limit allowed by the cam at E_1. This permits the wedge-shaped piece D_4, mounted on the slide D_1, to push the far side of the lever F (pivoted to the base at C_3) to the right. The near side of F

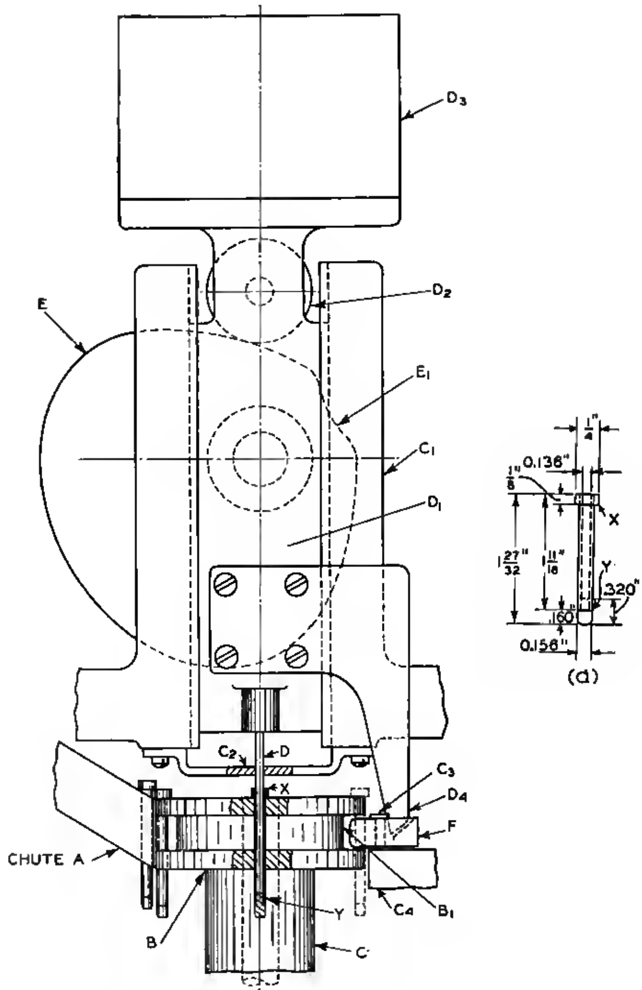


Fig. 2

is pushed into the groove B, and when the turret turns the defective piece is ejected. The lever F is reset by a cam after each operation. If the soldering is good, the load is supported by the piece for a short time while the roller D_2 is passing across the depression E_1, after which

the cam raises the weight, the turret turns and the piece is discharged into the O.K. chute after passing the lever *F*.

The saving effected by the automatic machine replacing the manual test is approximately $1,200 per year on a production of 2,500,000

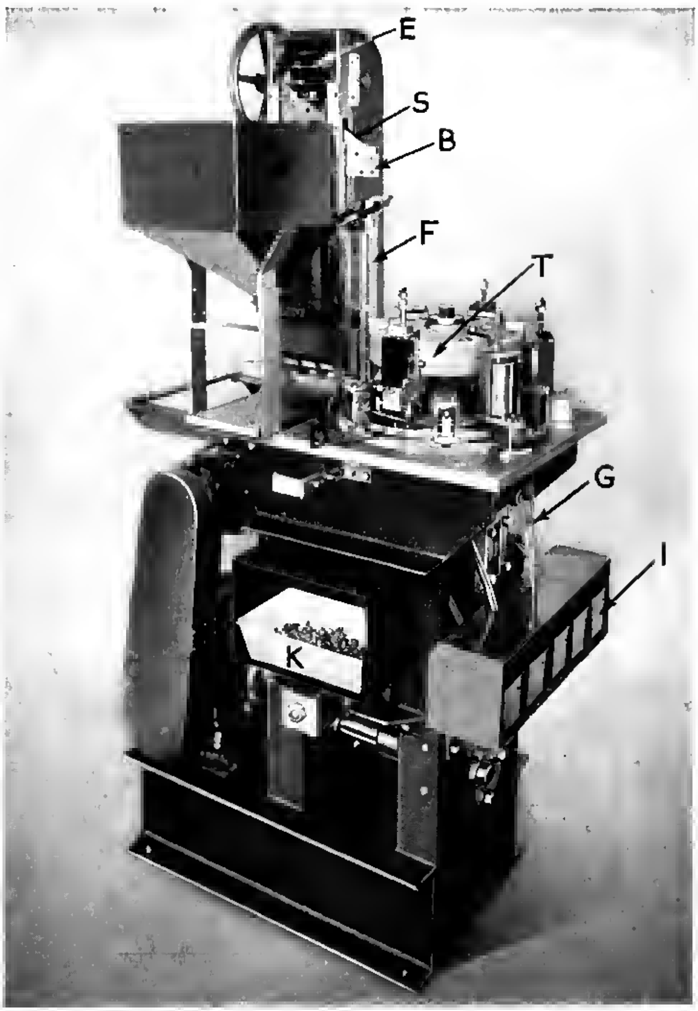


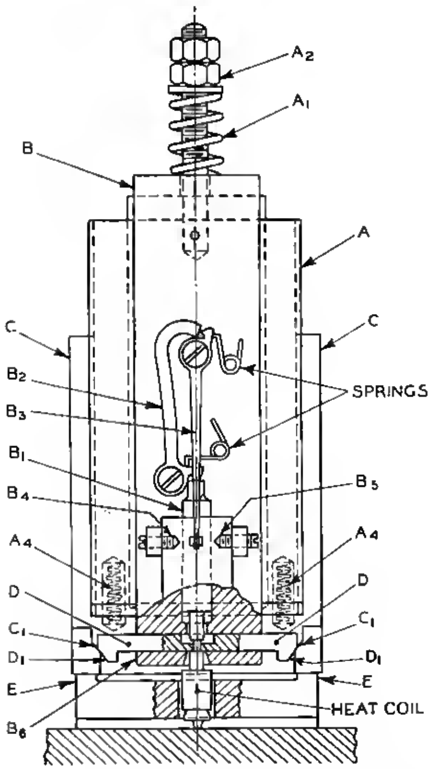
Fig. 3

pieces. However, by far the more important consideration is the elimination of an operation that was so monotonous and tiresome as to make it very difficult to keep any operator on it for more than a brief period.

Multi-Test Machine, Automatic Feed

An automatic gaging machine for applying four tests to a piece of telephone apparatus is shown in Fig. 3.

The part tested, shown in Fig. 4 (*a*), is a heat coil used to protect telephone exchange equipment against excessive electrical currents that may accidentally come in over the line wires. It consists of a tiny coil wound around a copper sleeve, into the end of which sleeve is



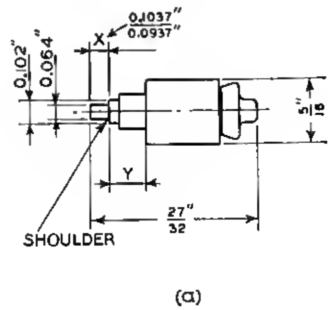


Fig. 4

soldered with low melting point solder a projecting pin. An excessive current through the coil melts the solder, allowing a contact spring to press the pin into the sleeve, which movement of the contact spring opens the circuit.

The machine gages the length of the pin X, the external length of sleeve Y, tests the strength of the soldered joint and measures the electrical resistance of the coil for high and low limits.

Referring to Fig. 3, there is an intermittently rotating disc D fitted

with twelve chucks for holding the parts to be tested and a vertically reciprocating turret head T which carries the gages and contact fixtures for making the tests.

The hopper H, chain elevator E and feed tube F are shown in more detail in Fig. 5. The coils are carried up from the hopper by the

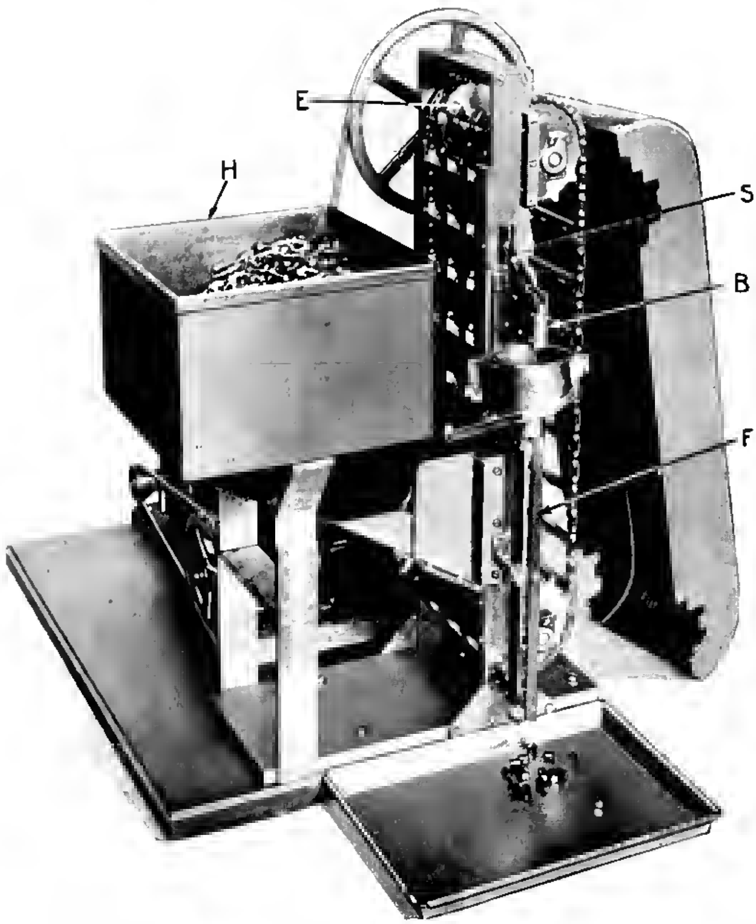


Fig. 5

elevator, two on each cross bar, and drop one after the other into the sloping chute S. Since the parts must be right end up for testing, the turning device B (shown in detail in Fig. 6) is placed at the end of the chute to turn over those pieces that are not already right end up. From the turning device the parts drop into the vertical feed tube F.

The chucks on the intermittently rotating disc take them one at a time from the feed tube and carry them under the gaging heads.

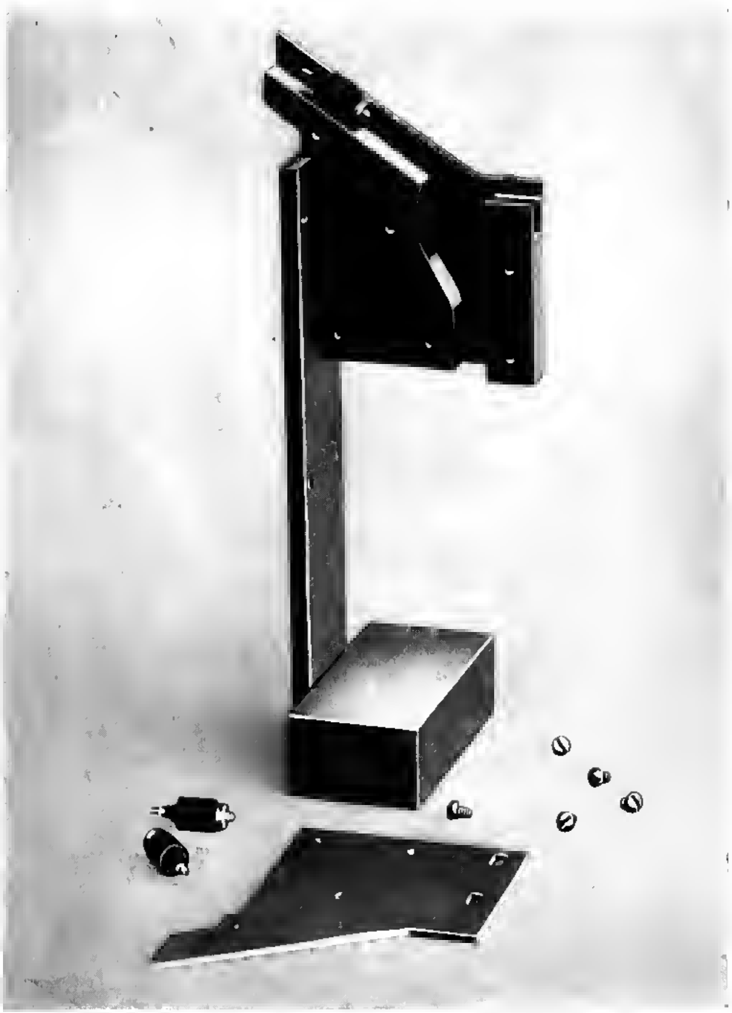


Fig. 6

In the first position the chuck picks a coil from the feed tube. In positions 2, 4, 6, 8 and 10 the coil is tested respectively for right end up, length of pin X, low limit of resistance, high limit of resistance and length of sleeve Y. At positions 3, 5, 7, 9 and 11 are located electro-magnets, each controlled by the testing device in the position preceding

it. These are for the purpose of ejecting defective parts so that if a part fails to meet the test at any position an electrical contact is closed which through the electro-magnets sets a trip at the next succeeding position of the chuck, and when the defective part reaches this position it is ejected from the chuck and through one of the tubes G falls into the proper compartment of the container I. At the 12th position the good parts are released from the chuck and fall into the pan K.

A multiple lever gage for this class of work is shown in Fig. 4, which shows the gage for length of pin X and also tests the strength of a

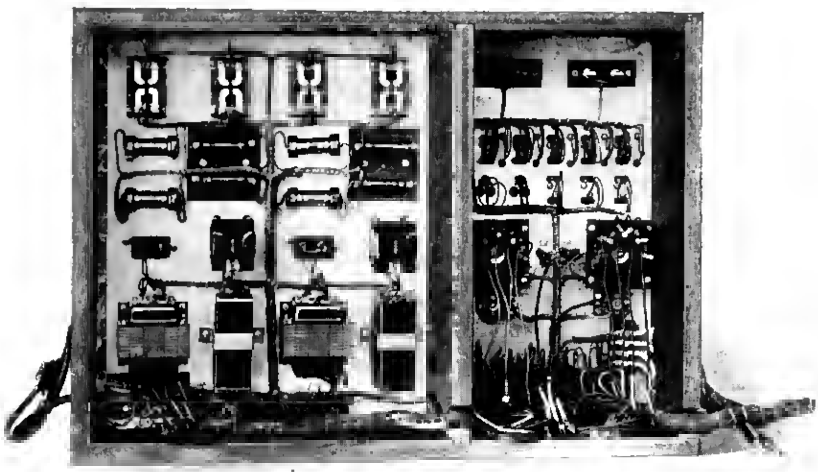


Fig. 7

soldered joint between pin X and sleeve Y. A is the body carrying two sliding members B and C. B carries the gaging mechanism and electrical contacts. B_6 is a preliminary centering guide for the heat coil. Centering slides D, D carried in B are normally held open by springs (not shown). A is normally lifted in C by springs A_4. Slide B is normally held down on A by means of spring A_1.

As the entire gage (A, B, C, D) descends, the heat coil is centered approximately by B_6. Then slide C is restrained by an anvil E, and as A continues downward the slides D, D are closed by the beveled surfaces C_1D_1, thereby centering coil and providing the gaging surface for the shoulder formed by the sleeve. As A continues downward, the gaging surfaces on D, D engage the shoulder and the pressure for operating the gage mechanism is transmitted from A to B through

spring A_1, which limits the testing pressure applied to the soldered joint.

If the length of pin is within limits, the electrical circuit remains open and the coil passes on to the next test. If it is too short, the circuit is closed through lever B_3 coming in contact with B_4, and if too long the contact is made with B_5.

If the soldered joint fails, the effect is the same as a short pin. In either case the tripping magnet operates and at the next position of

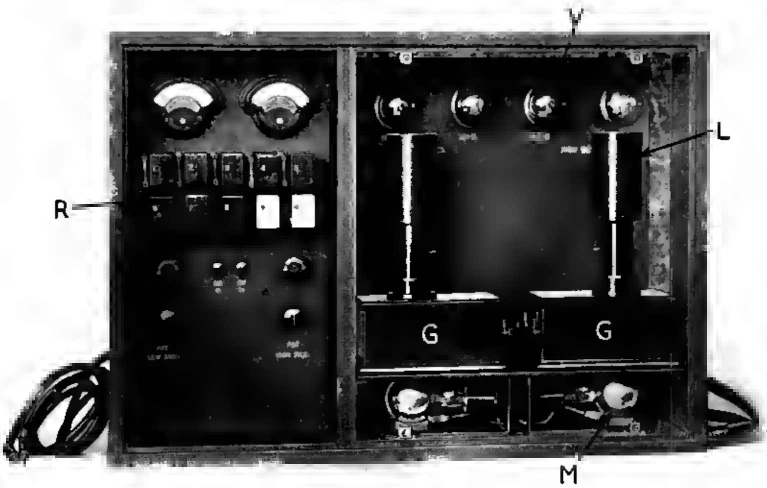


Fig. 8

the disc the defective part is released and drops into the proper container.

For testing the electrical resistance, contact is made with the coil terminals by the gaging machine and the resistance measurement proper is made by means of the apparatus shown in Figs. 7 and 8, which is essentially two Wheatstone resistance bridges, one for checking the resistance of the coil against a low limit and the other against a high limit. The galvanometers G, for indicating the balance of the bridges, each have a small rectangular, delicately pivoted coil which rotates between the pole piece of a strong magnet. The end of a long pointer attached to the coil is broadened out and contains a narrow slot which, in connection with a fixed slot, forms a shutter that passes or intercepts (depending on the position of the coil) a beam of light from a small lamp in the hood L passing to the photo-electric cell M.

The photo-electric cell is connected in the circuit of a vacuum tube amplifier, the tubes of which are shown at V. The position of the small shutter on the galvanometer needle is determined by the relative

value of the resistance of the coil under test to that of standards contained in the bridge. If this resistance is too high in one case or too low in the other, the shutter is closed, preventing the light beam from reaching the photo-electric cell. This in turn through the action

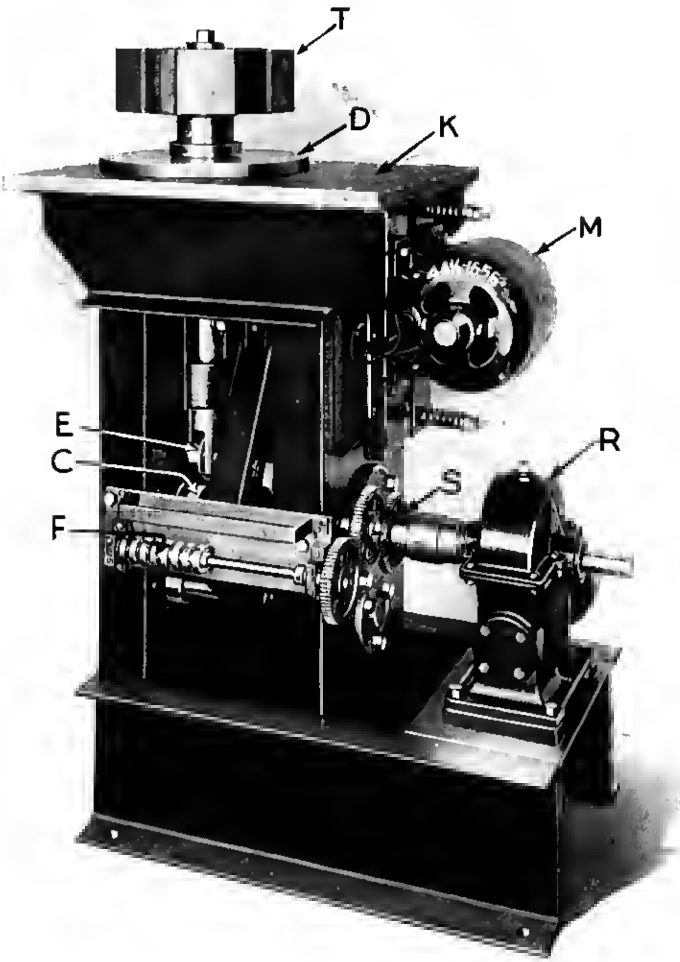


Fig. 9

of the vacuum tube amplifier and relays *R* actuates the trip on the machine which discharges the coil at the proper point.

While designing this machine much attention was given to producing a type that could be adapted readily to the testing of other parts requiring several operations.

Fig. 9 illustrates the fundamental parts of the machine. It is

individually driven by the motor M belted to the reducing gear R which is attached to the main shaft S. The turntable D is given an intermittent motion by a Geneva gear and the turret head T has a vertical reciprocating motion from the cam C on the main shaft through the roller E. The cams F are used for operating a series of electrical contacts which work in synchronism with the other parts of the machine controlling the sequence of testing operations and the disposition of parts.

The frame is built of welded structural steel. The turntable may be fitted with a variety of chucks or holding fixtures and the turret with various forms of gages or testing apparatus. The cams and gear ratios may be changed to accommodate a wide range of testing requirements. Space is provided at K for a hopper or other feeding device. This type of machine is suitable for multiple tests on parts requiring special holding fixtures.

Multi-Unit Testing Machine—Semi-Automatic Feed

An entirely different type of gaging and testing machine is shown in Figs. 10 and 11, which, as illustrated, is equipped for testing porcelain

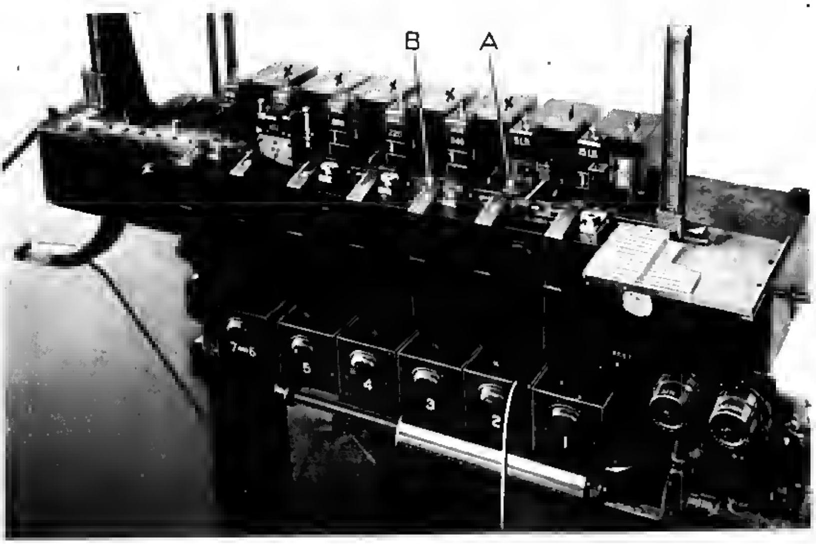


Fig. 10

protector blocks used for protecting telephone apparatus against high voltage electrical currents or static discharges.

These are porcelain blocks $1\frac{1}{4}$ in. x $\frac{3}{8}$ in. x $\frac{9}{32}$ in., having a recessed

surface into the center of which is inserted a small carbon block having a face 0.0370 in. x 0.110 in., cemented in with a low melting point glass. The face of the carbon block is underflush with the rim of the porcelain block, Fig. 12 (*a*).

Fig. 11

As shown in Fig. 11, the blocks are being stacked by hand in the top of a vertical chute from which they are automatically fed to the machine at the bottom, but the feeding arrangement shown separately in Fig. 13 is now being added. This consists of a rotating disc having two V-shaped grooves in the surface and above it a stationary plate having a spiral slot. The operator places the blocks rear side up (by

sense of touch) against the front side of the central opening of the stationary plate, three blocks being shown in this position at A. The disc carries them into the spiral slot at B and while they are passing the front opening in the top plate at C they are given a visual inspection.

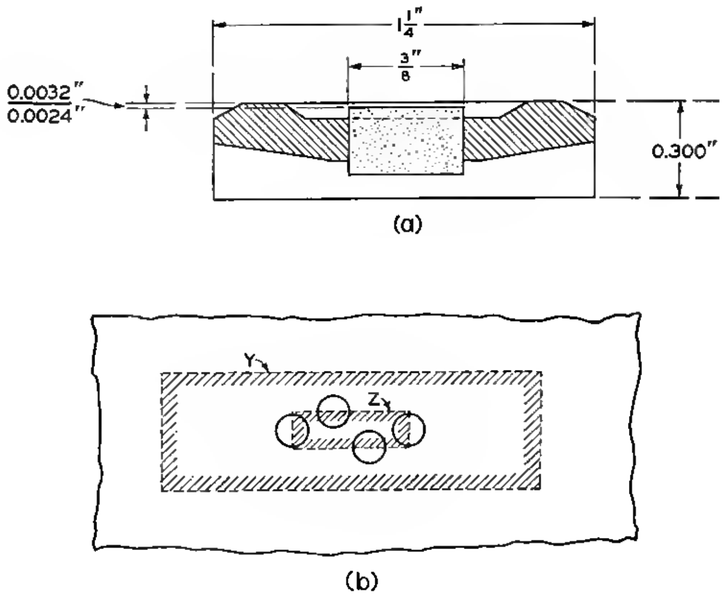


Fig. 12

During the second round they are turned over by the action of the two V grooves in the rotating disc and the radial motion given them by the spiral slot, and the front face is turned up for visual inspection during the second passage across the front opening at D. Any with visible defects are picked off by hand, while the others passing on through the last turn of the spiral at E are fed into the machine (Fig. 10) for the following gaging operations:

1. 15 lb. weight test for defective cementing.
2. 5 lb. weight test to detect misplaced inserts.
3. Gage height of back face of insert—minimum 0.046 in.
4. Gage thickness of block—maximum 0.220 in.
5. Gage thickness of block—minimum 0.205 in.
6. Gage the underflush dimension of insert which must be maximum 0.0032 in., minimum 0.0024 in., for at least half the area of the face of the carbon insert.
7. Gage the underflush dimension for minimum 0.0024 in. over entire face of insert.

The gage for operation No. 6 has four $\frac{1}{8}$ in. plungers (*P*, Fig. 15) arranged to make contact with the insert as shown at (*b*), Fig. 12, and the electrical contacts of the gage controlled by the plungers are connected to a bank of relays so that if any three or all four of the gage points are within the limits the block is passed, but if two or more are outside the limits the block is rejected. This gage, shown in Figs. 14, 15, 16, and 17, is without pivots, the moving parts being controlled

Fig. 13

by thin steel reeds as shown in Fig. 14. Fig. 15 shows a partial, and Fig. 16 a complete, assembly, while Fig. 17 shows the equalizing levers for centering the block in the gage. Using master steel gage blocks, the contact points are adjusted by the screws *A*, Fig. 16, to accept blocks if the underflush dimension is minimum 0.0024 in. and maximum 0.0032 in., and reject blocks when the dimension is 0.0023 in. or less or 0.0033 in. or more.

The single plunger gages used for operations 2, 3, 4, 5 and 7 are also of the reed type and are similar to that shown in Fig. 18. These have a sliding electrical contact instead of a point contact, the pointer *A*

sliding on the surface of the insulated block B and making contact with the flush metal insert C.

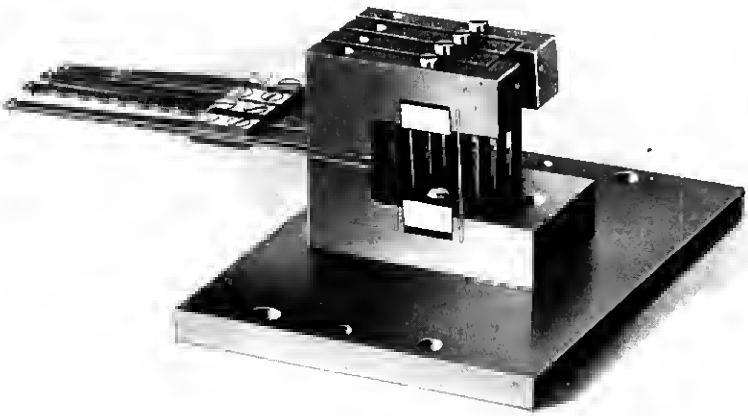


Fig. 14

Considerable experience has been gained in the design and use of the reed type gages and they are proving very satisfactory for a wide variety of uses. They are relatively inexpensive to build, require but

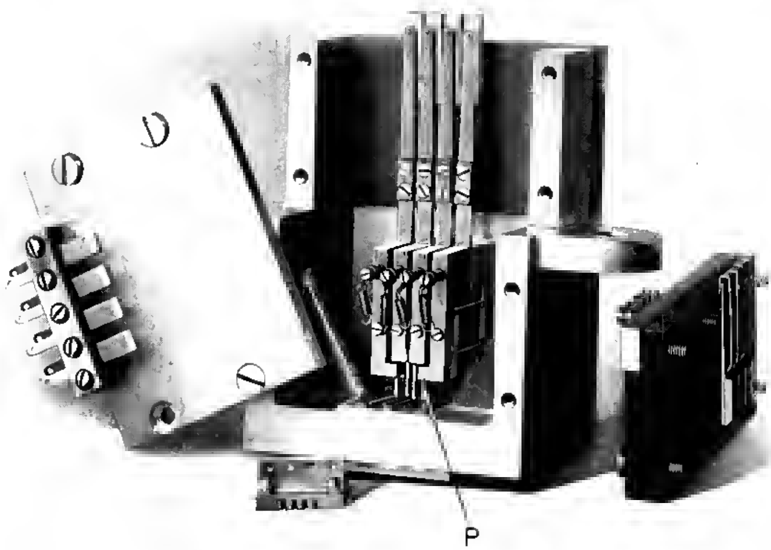


Fig. 15

little maintenance, the pressure on the gaging point may be kept low if desired and they are reliable in action.

Following each gaging operation the blocks pass between air blast tips A, Fig. 10, and the square tubes B marked 1 to 7 leading to receptacles bearing the same numbers. The electrical contact in each gage, which is closed by a defective block, sets a trip connected to the adjacent air tube so that, as the block passes, the air cock is opened for an instant and the defective block is blown out of the test line into the tube, through which it falls into the proper container. A small air compressor is installed as part of the machine.

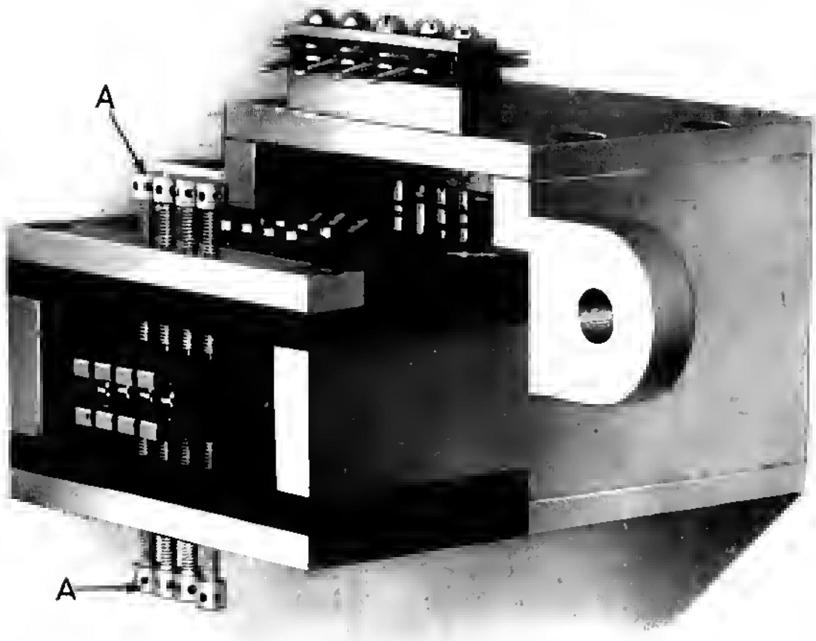


Fig. 16

The O.K. blocks pass along to the automatic packing attachment E (shown in more detail in Fig. 11), which places 100 of them in a box in layers of five each with cardboard separators between layers. The empty boxes are shown in the magazine F, the separators at G, and the filled boxes emerging at H.

The feed table shown in Fig. 13 will be placed at the same end of the machine as the packing attachment and the blocks will be carried

from the feed table to the far end of the machine by a conveyor. By this arrangement one operator can feed the machine, make the visual inspection and remove the finished packages. This machine will effect a saving of $8,000 per year over the cost of hand gaging methods

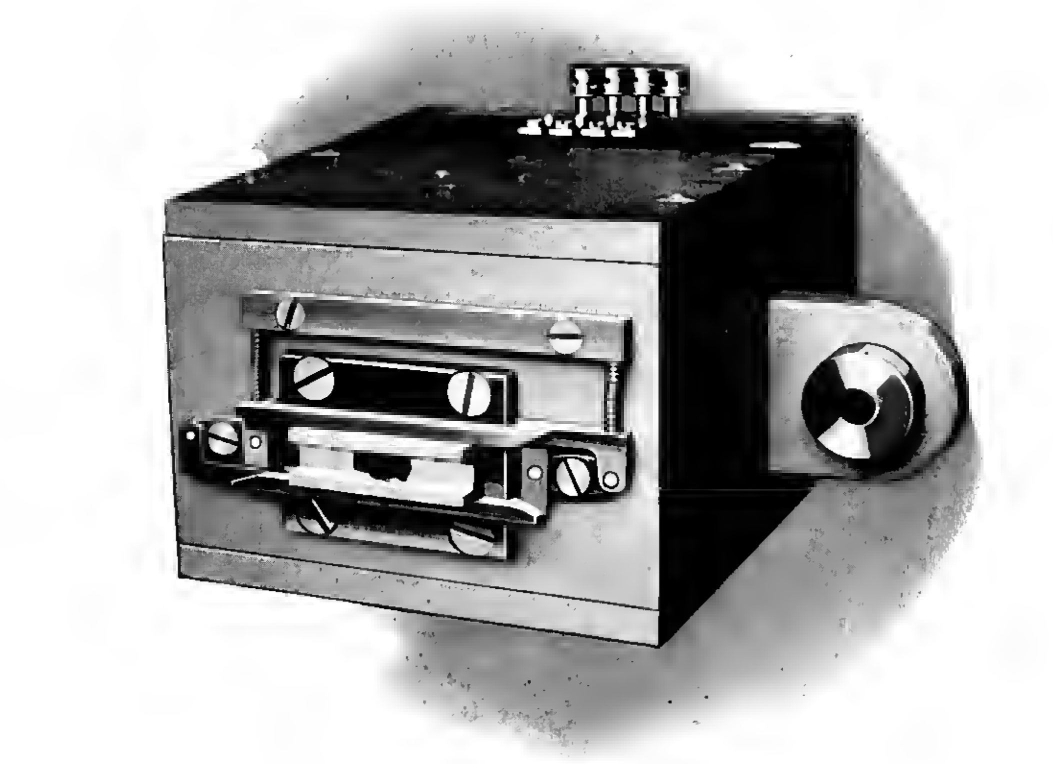


Fig. 17

on an output of 4,500,000 blocks. A similar machine is being built for another size of blocks.

Each gage with its associated equipment is an independent unit as shown in Fig. 19. The gages are located at *G*, either above or below the working surface. Relays and other electrical apparatus at *E*. The solenoid for opening the air cock is shown at *S* and the air blast tip at *T*. The connection for the electrical supply for each unit is made with the cord and plug *P*. The cams *C* and contact springs *D* operate in synchronism with the other parts of the machine and control details of the gaging operation and the air blast.

The main shaft of the machine can be seen at A, which drives the disc B through worm gears. When the units are attached the pin K engages a slot on a disc attached to the rear of the unit shaft I. Attached to the front end of the same shaft are two eccentrics H (shown in Fig. 20) which operate the feeding device located just back of the blocks shown in the illustration, Figs. 10 and 11.

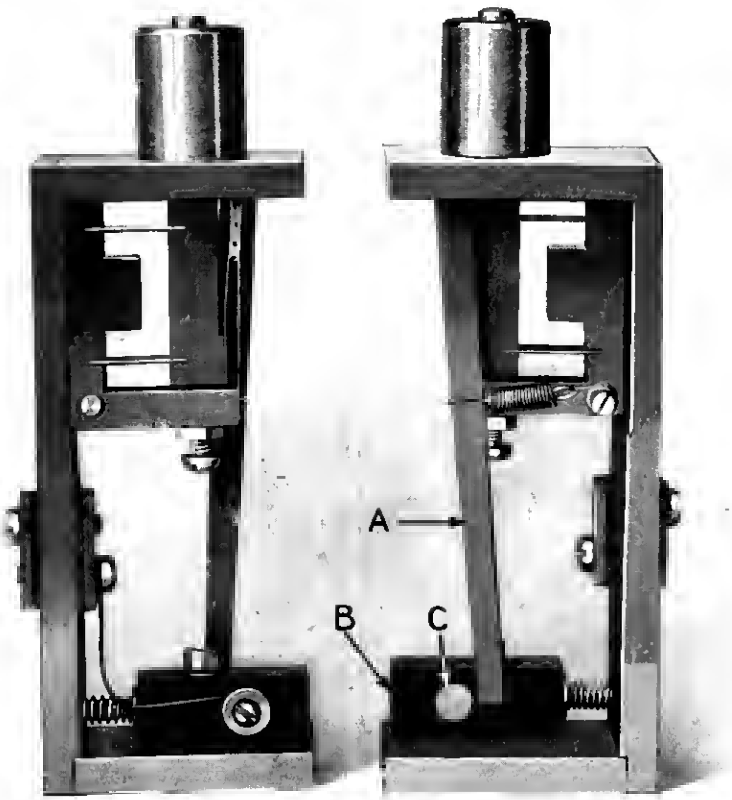


Fig. 18

The feeding mechanism (Fig. 20) is of the finger bar type consisting of two reciprocating bars A and B, both having the same travel.

Fig. 20 indicates the relative position of the driving parts. Finger bar A is operated by a bell crank gear segment and eccentric properly timed to step the protector blocks to the gaging position immediately prior to the gaging operation.

Feed fingers C are so located in this finger bar that the protector blocks are centrally located under the gage when the finger bar comes to rest at its forward position.

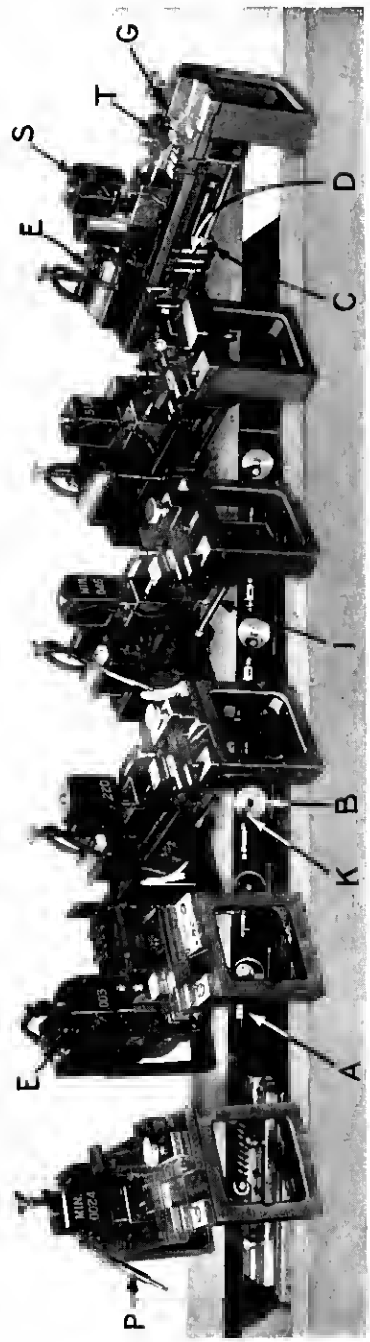


Fig. 19

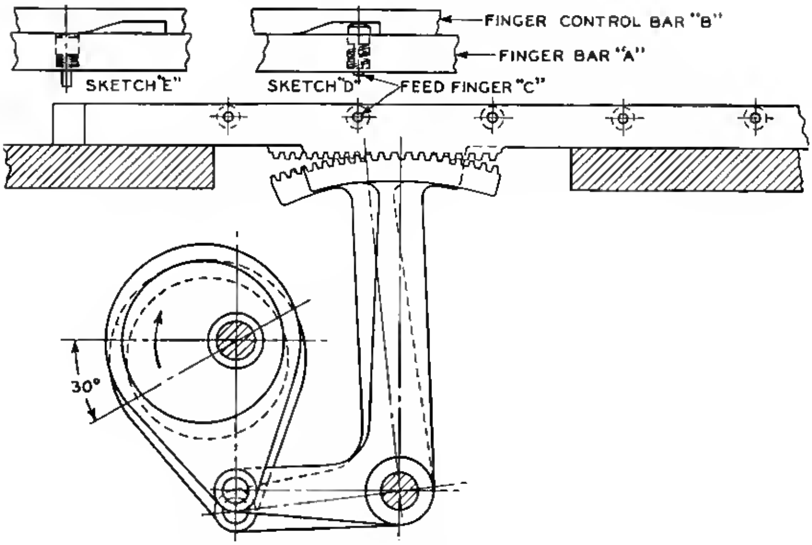


Fig. 20

The finger control bar *B* is likewise operated by a bell crank gear segment and eccentric but is set with a thirty degrees lag. The effect of this lag is illustrated in sketches *D* and *E* which show the manner in which the feed fingers *C* are withdrawn on the return stroke of the finger bar.

Economic Considerations

A comparison of hand versus machine gaging is given in Table I. In this particular case the quality of the inspection work was bettered approximately 100 per cent, while the cost was reduced 60 per cent. While this showing is rather better than the average, the tendency in most instances is in the same direction.

Like the turret machine previously described, this one was designed with the idea of making it readily adaptable for similar work on other parts. The number of units and thereby the number of operations on a machine may be varied greatly. A unit may be quickly removed for adjustment or repair and easily replaced. If the conditions warranted, spare units could be provided and an adjusted unit put in the place of a defective one in fifteen or twenty minutes.

The frame is built of welded structural steel. The machine is a complete unit with individual motor drive requiring only the attachment of the electric power supply.

The unit system for the equipment provides a wide latitude in the choice of gaging and testing fixtures to be used and the details of operating them.

TABLE I

COMPARISON OF THE ECONOMIC FACTORS ON TESTING OF PROTECTOR BLOCKS BY MACHINE METHOD AND BY MANUAL METHOD

	Machine Method	Hand Method	Remarks
Capacity	8,000,000 per year, 1 machine at 3,600 per hour	8,000,000 per year, 9 hand gages required	
Cost of Equipment	1 machine at $10,000	9 gages at $150—$1,350	Machine method requires $8,650 additional first cost, meaning an annual yearly charge, at 8%, of $670.
Cost of Labor	1½ operators at $1,920 = $2,880 per year (including loading)	6 operators at $1,920 = $11,520 per year (including loading)	Machine method gives a saving of $8,640 per year in labor costs.
Cost of Power	$40 per year	0	Machine method costs $40 a year additional for power.
Floor Space	Machine requires 35 square feet	6 operators require 90 square feet	55 square feet saved by machine.
Maintenance	Cost of maintenance at $130 per million blocks = $1,040 per year	Cost of maintenance of 9 gages per year = $1,560	$520 saved by machine method, nearly 30%.
Accuracy — Repeating results on parts that vary from tolerance limit by .0001 in.	95% (See note below)	45% Low degree of accuracy due to (a) plurality of gages, (b) plurality of operators	Degree of accuracy doubled.

Note: This means that a master gage or parts that are .0001 in. outside the tolerance limit will be rejected, in the first case, an average of 95 times in 100 trials, and in the second case 45 times. Parts that are .0001 in. within the tolerance limits will be passed as good in the same ratios. The disposition of parts that vary more than .0001 in. either way from the tolerance limits would follow the normal probability law. The figures given do not give any indication of the very small percentage of defective parts that would be passed as good or good parts classed as defectives, as these would depend upon the relative number of defectives and the distribution of their variations from the tolerance limit, as well as the precision of the methods given above.

The development of machine gaging has been greatly aided by the development of accessory parts, such as reliable indicating gages, chromium-plated parts, sensitive but sturdy relays, vacuum tube amplifiers and photo-electric cells.

Sampling methods or percentage inspection are applicable to parts that are made under conditions that may be considered approximately uniform or, as a statistician would say, under "a constant system of causes." Piece parts made in the punch press and screw machine are good examples of this. Many other classes of operations, particularly those in which some part is manual, produce parts which are not so uniform. As the variability increases, or as the requirements for precision become more exacting, the possibilities of sampling inspection become less attractive.

In many cases the conditions and requirements are such that only detail inspection or gaging is satisfactory.

In some instances automatic machine gaging of the entire output will cost less than a sampling system in which there must be included with the direct cost of inspection the cost of some additional supervision and control.

The possibilities so far as designs are concerned seem almost unlimited, so that the question of when to apply such methods becomes purely an economical one in which the number of parts to be handled, the difficulty, unpleasantness or tiresomeness of the operation, the precision required, and the cost of suitable labor become the controlling factors.

Aside from the question of cost, it is often a matter of great satisfaction to place an objectionable hand operation on the machine and release the labor for more pleasant and useful work.